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Biological Components of Galveston Bay

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Distribution and Abundance

Estuarine Vegetation

PETER F. SHERIDAN—The plant life of Galveston Bay includes phytoplankton in the water column, benthic microflora, macroalgae, submerged aquatic vegetation and emergent vascular plants. Some groups are so dense that they are major sources of physical structure for other estuarine organisms, while some groups are major producers of organic materials for assimilation by consumers. Other functions of vegetation include refuge from predators, maintenance of water quality by filtering runoff and tidal inputs, and shoreline stabilization.

Phytoplankton—The phytoplankton of upper Galveston and Trinity Bays is composed of at least 132 species, including diatoms (54 taxa), green algae (45 taxa), blue-green algae (14 taxa), dinoflagellates (9 taxa), euglenoids (7 taxa), cryptophytes (2 taxa), and golden-brown algae (1 taxon) (1). Many of these species, particularly the green algae, are freshwater forms entering via river discharge. Over an annual cycle (September 1975-August 1976), the mean percentage of the standing crop for each division was found to be diatoms (41.6 percent), green algae (24.2 percent), blue-green algae (23.0 percent), dinoflagellates (5.9 percent), euglenoids (2.6 percent), and others (2.7 percent). Major peaks in phytoplankton density occurred in late winter and mid-summer. The winter peak was due to the diatoms **Skeletonema costatum** and **Cyclotella menenghiniana**, while the summer peak in densities was due to a bloom of the blue-green **Oscillatoria** sp. As a group, diatoms were the dominant phytoplankters in November, December and February-June (**Skeletonema** and **Cyclotella** in cold months, **Nitzschia closterium**, **Navicula abunda** and **Thalassionema nitzschoides** in warmer months). Green algae were a consistent 20 to 30 percent of the monthly standing crops, and **Ankistrodesmus** sp. bloomed in September-October. Blue-green algae were relatively abundant July to October, and a bloom of **Oscillatoria** in July represented 70 percent of the standing crop. The dinoflagellate **Prorocentrum** sp. comprised 45 percent of the total density in January. Euglenoids such as **Euglena** spp. and **Eutreptia** spp. were relatively abundant in May and August. Lower salinity stations were dominated by blue-green and green algae while high salinity sites were dominated by diatoms.

Similar studies on phytoplankton distribution and abundance have not been conducted in lower Galveston, East or West Bays.

Benthic Microflora—Components of the benthic microflora have been examined in a descriptive sense (2-4), but little information on temporal or spatial distribution is available. Thirty-three genera

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Table 2.1. Benthic Algae Collected from Bay Sediments (2) and Beach Sands (4) in the Galveston Bay System.

Green Algae	Blue-green Algae	Diatoms
Bracteacoccus	Anabaena	Achnanthes (2)
Characium	Anacystis	Actinoptychus (3)
Chlamydomonas	Aphanocapsa	Amphora (3)
Chlorosarcina	Aphanothece	*Coscinodiscus (10)
Chlorosarcinopsis	Calothrix	*Cyclotella (3)
Chlorococcum	Gloeocapsa	Diatoma (1)
Cylindrocystis	Lyngbya	*Diploneis (4)
Eremosphaera	Myxosarcina	Epithemia (1)
Gloeocystis	Nostoc	Eunotogramma (1)
Hormidium	Oscillatoria	Mastogloia (1)
Oedocladium	Schizothrix	Melosira (2)
Pleurastrum	Spirulina	Navicula (4)
Radiosphaera	Synechococcus	Nitzschia (9)
Stichococcus	Synechocystis	Opephora (1)
Tetracystis	Xenococcus	Pinnularia (1)
Tetraedon		Pleurosigma (4)
		Rhopalodia (2)
		*Skeletonema (1)
		Stenopterobia (1)
Cryptophytes	Euglenophytes	Stephanodiscus (1)
Cryptomonas	Euglena	Surirella (1)
		Synedra (1)

(n) = number of species in genus, if given
* = most abundant

of algae were identified from Galveston Island beach sands, and 22 genera (56 species) of diatoms were identified from bay sediments (Table 2.1). The diatoms **Coscinodiscus, Diploneis, Cyclotella** and **Skeletonema** were noted as being very abundant (2), the latter two genera also dominating the phytoplankton as noted previously. Diatoms were the main component of the benthic microflora in waters deeper than 0.5 m, while blue-green algae dominated the shallow water and tidal flats (3). Algal densities could not be related to depth, sediment type, Eh, pH or salinity.

Macroalgae—There has been no survey of macroalgal types over the whole bay system. Several faunal surveys (9, 13, 24) noted that, where present, the macroalgae is represented by **Enteromorpha, Ectocarpus, Dictyota, Sargassum, Polysiphonia** and **Gracilaria**. The major study of macroalgae was limited to Galveston Island proper (46), finding 19 genera and 28 species over a two-year period (Table 2.2). The gulf shore community is composed of **Cladophora, Bryocladia** and **Ceramium** in summer and shifts to **Enteromorpha, Bangia** and **Gelidium** in winter. The bay shore community is barren in the summer and is primarily **Enteromorpha** and **Ectocarpus** during winter. The flora is considered depauperate relative to other Gulf estuaries.

Submerged aquatic vegetation—Submerged aquatic vegetation is limited in areal extent. On the Trinity River delta, the submerged freshwater plants **Vallisneria americana** (tapegrass) and **Sagit-**

Table 2.2. Benthic Macroalgae of Galveston Island Grouped by Maximum Growth Periods(46).

Summer-Fall	Winter-Spring	Indeterminant (not enough data)
Bryocladia cuspidata	Ectocarpus siliculosus	Dictyota dichotoma
Ceramium strictum	Petalonia fascia	Gracilaria foliifera
Cladophora dalmatica	Enteromorpha clathrata	Sargassum fluitans
Cladophora linum	Enteromorpha flexuosa	Sargassum natans
Polysiphonia gorgoniae	Enteromorpha lingulata	Vaucheria sp.
Polysiphonia denudata	Enteromorpha prolifera	
Polysiphonia tepida	Ulva lactuca	
Spyridia filamentosa	Gelidium crinale	
Chaetomorpha linum	Bangia fuscopurpurea	
Erythrocladia subintegra	Polysiphonia subtilissima	
Erythrotrichia carnea		
Goniotrichum alsidii		
Achrochaetium sp.		

taria kurziana (strap-leaf) are currently found in mixed stands (5). **Vallisneria** has also been found in the Chocolate Bay area off West Bay (24). Extensive **Ruppia maritima** (widgeon grass) beds were once located in shallow marginal waters of Trinity Bay and upper Galveston Bay (6-8). East Bay was found to be devoid of submerged vegetation (9). **Ruppia** was also scattered in various embayments along lower Galveston Bay and West Bay (10-13). Western West Bay, Christmas Bay and Bastrop Bay harbored seagrass beds dominated by **Halodule wrightii** (shoal grass) and lesser amounts of **Thalassia testudinum** (turtle grass) and **Halophila engelmannii** (13, 14). The areal extent of submerged vegetation has apparently declined from approximately 21 km^2 around 1960 (6-8, 12) to <1 km^2 by 1979 (15). There have been no studies of seasonal growth or distribution of submerged vegetation in the Galveston Bay system, and no actual bay-wide site surveys for species composition and distribution.

Marshes, woodlands and swamps—Emergent vegetation can be classified as salt, brackish or freshwater marshes, fluvial woodlands and swamps. These wetlands are large-scale contributors to estuarine productivity in terms of particulate matter, nutrients, structure, protection and substrate. Salt marshes cover an estimated 140 km^2 (12). Species such as **Spartina alterniflora, Batis maritima, Salicornia** spp. and **Juncus roemerianus** are most common in the more frequently flooded areas, while **Borrichia frutescens, Monanthochloe littoralis, Distichlis spicata, Suaeda** spp., **Iva** spp. and **Aster** spp. are less common (Table 2.3). **Spartina alterniflora** is the dominant plant in subsiding salt marshes due to almost constant flooding. Brackish marshes (230 km^2; 12) are of moderate salinity regimes (1 to 18 ppt) but are flooded by storm tides from the bay and by freshwater inundation from rainfall and runoff, thus they have a mixture of vegetation types (Table 2.3). Plants frequently occurring in fresher areas include **Scirpus maritimus, S. californicus** and **S. americanus, Alternathera philoxeroides, Bacopa monnieri, Typha** spp., **Paspalum lividum** and **Phragmites australis**, while plants in the more saline brackish marshes include **Spartina patens** and **S. spartinae, Scirpus olneyi** and **S. maritimus, Paspalum vaginatum, Juncus roemerianus** and species from higher salt marshes. Lower elevation brackish marshes are dominated by **Scirpus, Typha, Eleocharis** and **Bacopa**, whereas in higher elevation brackish marshes **Spartina spartinae** and **S. patens** are more common. Fresh marshes are generally beyond all salt water intrusion except during hurricane surges. There are approximately 40 km^2 of fresh marshes, primarily in the Trinity and San Jacinto River systems (12). Low fresh marshes are characterized by **Typha** spp., **Scirpus americanus** and **S.**

Table 2.3. Typical Plants Found in Galveston Bay Wetland Environments (15).

Salt Marsh

Spartina alterniflora	smooth cordgrass
Batis maritima	saltwort
Salicornia virginica	glasswort
Salicornia bigelovii	glasswort
Distichlis spicata	seashore saltgrass
Borrichia frutescens	sea-oxeye
Monanthochloe littoralis	shoregrass
Juncus roemerianus	needle rush
Suaeda sp.	seablite or seepweed
Lycium carolinianum	Carolina wolfberry
Spartina spartinae	gulf cordgrass
Spartina patens	marshhay cordgrass
Iva frutescens	bigleaf sumpweed
Iva angustifolia	narrowleaf sumpweed
Limonium nashii	sea-lavender
Scirpus maritimus	salt-marsh bulrush
Sporobolus spp.	dropseed
Sesuvium portulacastrum	sea purslane
Heliotropium curassavicum	salt heliotrope

Brackish Marsh

Spartina spartinae	gulf cordgrass
Spartina patens	marshhay cordgrass
Borrichia frutescens	sea-oxeye
Distichlis spicata	seashore saltgrass
Monanthochloe littoralis	shoregrass
Scirpus maritimus	salt-marsh bulrush
Scirpus americanus	three-square bulrush
Scirpus californicus	California bulrush
Scirpus olneyi	Olney bulrush
Alternanthera philoxeroides	alligatorweed
Typha domingensis	narrowleaf cattail
Typha latifolia	common cattail
Spartina cynosuroides	big cordgrass
Phragmites australis	common reed
Eleocharis parvula	dwarf spikerush
Cyperus spp.	flatsedge
Enchinochloa crusgalli	barnyard grass
Leptochloa spp.	sprangletop
Bacopa monnieri	coastal waterhyssop
Aster tenuifolius	saline aster
Aster subulatus	saltmarsh aster
Aster spinosus	spiny aster
Paspalum lividum	longtom
Paspalum vaginatum	seashore paspalum
Setaria geniculata	knotroot bristlegrass
Zizaniopsis miliacea	giant cutgrass
Solidago sempervirens	seaside goldenrod
Baccharis halimifolia	groundsel bush
Iva frutescens	bigleaf sumpweed
Iva angustifolia	narrowleaf sumpweed
Iva annua	seacoast sumpweed
Sesuvium portulacastrum	sea purslane
Salicornia spp.	glasswort
Limonium nashii	sea-lavender
Juncus roemerianus	needle rush
Lycium carolinianum	Carolina wolfberry
Sporobolus spp.	dropseed
Fimbristylis castanea	fimbry
Hydrocotyle spp.	pennywort

Fresh Marsh

Spartina spartinae	gulf cordgrass
Typha latifolia	common cattail
Typha domingensis	narrowleaf cattail
Scirpus americanus	three-square bulrush

Scirpus californicus	California bulrush
Paspalum lividum	longtom
Eleocharis spp.	spikesedge
Cyperus spp.	flatsedge
Alternanthera philoxeroides	alligatorweed
Juncus spp.	rush
Ludwigia spp.	seedbox
Sagittaria spp.	arrowhead
Pontederia sp.	pickerelweed
Polygonum spp.	knotweed
Phragmites australis	common reed
Bacopa monnieri	waterhyssop
Echinodorus spp.	burrhead
Eichhornia crassipes	water hyacinth
Rhynchospora sp.	beakrush
Fimbristylis spp.	fimbry
Echinochloa crusgalli	barnyard grass
Leptochloa spp.	sprangletop
Spartina patens	marshhay cordgrass
Lemna spp.	duckweed
Hydrocotyle spp.	marsh penny-wort
Zizaniopsis miliacea	southern wildrice
Sesbania drummondii	rattlebush
Baccharis halimifolia	groundsel bush
Cephalanthus occidentalis	buttonbush
Salix nigra	black willow

Transitional Areas

Spartina spartinae	gulf cordgrass
Cynodon dactylon	bermudagrass
Borrichia frutescens	sea-oxeye
Aster spinosus	spiny aster
Paspalum monostachyum	gulfdune paspalum
Paspalum lividum	longtom
Panicum spp.	panicum
Rhynchospora spp.	beakrush
Andropogon virginicus	broomsedge bluestem
Andropogon glomeratus	bushy bluestem
Iva annua	seacoast sumpweed
Aristida spp.	threeawn
Setaria spp.	bristlegrass
Helianthus spp.	sunflower
Sorghum halepense	johnsongrass
Cassia fasciculata	partridge pea
Cyperus spp.	flatsedge
Eleocharis spp.	spikesedge
Scirpus spp.	bulrush
Croton spp.	doveweed
Spartina patens	marshhay cordgrass
Baccharis halimifolia	groundsel bush
Sesbania drummondii	rattlebush

Fluvial Woodlands

Salix nigra	black willow
Celtis spp.	hackberry/ sugarberry
Fraxinus spp.	ash
Ulmus crassifolia	cedar elm
Ulmus americana	American elm
Quercus aquatica	water oak
Quercus lyrata	overcup oak
Quercus phellos	willow oak
Quercus stellata	post oak
Quercus virginiana	live oak
Liquidambar styraciflua	sweetgum
Ilex vomitoria	yaupon
Cephalanthus occidentalis	buttonbush
Sapium sebiferum	Chinese tallow
Pinus taeda	loblolly pine
Carya aquatica	water hickory
Carya illinoensis	pecan
Populus deltoides	cottonwood
Plantanus occidentalis	American sycamore
Planera aquatica	water elm
Acacia farnesiana	huisache
Parkinsonia aculeata	retama
Tamarix gallica	salt cedar
Sabal minor	dwarf palmetto
Taxodium distichum	bald cypress
Acer negundo	boxelder

Swamp

Taxodium distichum	bald cypress
Planera aquatica	water elm
Carya aquatica	water hickory
Cephalanthus occidentalis	buttonbush

californicus, Phragmites australis, Eleocharis spp., **Cyperus** spp., **Juncus** spp., **Ludwigia** sp., **Sagittaria** spp. and **Paspalum lividum** (Table 2.3) (1, 15). Higher fresh marshes are typified by **Spartina spartinae, Paspalum** spp., **Polygonum** spp., **Panicum** spp., **Borrichia, Rhynchospora macrostachya, Fimbristylis** sp., **Aster** spp. and **Sesbania drummondii.** Many species of **Spartina** exhibit broad salinity tolerances and are found in several categories of marsh. Fluvial woodlands along floodplains cover 450 km^2 (12) and support a variety of water-tolerant trees and shrubs (Table 2.3), including **Fraxinus** spp., **Salix nigra, Ulmus** spp., **Celtis** spp., **Carya** spp. and **Quercus** spp. Swamps containing saturated soils or nearly permanent standing water comprise 50 km^2 (12) and are dominated by **Taxodium distichum** (Table 2.3). Additional information on wetland plants is also available (16).

Between wetland surveys of 1956 and 1979, several changes were noted in vegetation patterns in the estuary: (1) expansion of open water into former marshes and woodlands; (2) expansion of marshes along the bay side of barrier islands into prior tidal flats; (3) formation of wetlands farther up creek valleys; (4) landward expansion of existing marshes; (5) reduction of submerged vegetation; and (6) reduction or modification of wetlands by human activities (15). Of primary concern are the losses of 63 km^2 of fresh marsh and 42 km^2 of salt and brackish marshes during this period. These losses are ascribed to such activities as channelization, impoundments, filling and subsidence associated with subsurface petroleum or water extraction.

Invertebrates

Invertebrates within the Galveston Bay system are discussed by component groups such as zooplankton, benthos, and mobile and sessile macrofauna. While there have been a number of studies of invertebrates in this area, there are no synoptic zooplankton or macrofaunal surveys on a bay-wide basis.

Zooplankton—A 12-month study of zooplankton in the upper Galveston and Trinity Bay areas (1) revealed 70 species representing nine phyla. The most abundant plankters included copepods (primarily **Acartia tonsa,** followed by **Labidocera, Cyclops** and **Oithoina**) and barnacle nauplii (**Balanus** spp.); in fact, these two phyla plus a mixed assemblage of copepod nauplii and copepodites represented >70 percent of the zooplankton in 11 of 12 months. Other phyla included rotifers (**Asplancha, Brachionus, Keratella**), dinoflagellates (**Noctiluca scintillans**) and larvaceans (**Oikopleura**). Zooplankton densities peaked in April (dominated by copepod nauplii and **Noctiluca**) and August (**Acartia** and copepod nauplii). Barnacle nauplii were most dense in late winter-early spring. Fluctuations in zooplankton densities were not linked to variations in river flow, but salinity regimes regulated species composition and seasonal distribution.

A three-and-a-half-year study (17) of the larger zooplankters in the same region (mouth of the San Jacinto River and southern Trinity Bay) identified 94 taxa dominated by crustaceans and fishes. Crab larvae, tentatively identified as **Rhithropanopeus harrisii,** were the most abundant group followed by other crustaceans such as **Petrolisthes armatus, Pinnixa** sp., **Palaemonetes** spp. and **Callinectes** spp., and by the fishes **Brevoortia patronus** and **Anchoa mitchilli.** Two broad seasonal groups were detected relating to abundance of organisms, with a "warm" season characterized by many larval crustaceans and few fishes and a "cool" season where the reverse trend was found.

A 16-month study of the zooplankton of Christmas Bay (18) indicated that this high salinity embayment hosted a permanent zooplankton assemblage of three species (**Mnemiopsis mccradyi,** a ctenophore, and **Acartia tonsa** and **Oithoina colcarva,** copepods) apparently unaffected by temperature and salinity fluctuations. Other taxa such as larval crustaceans, other copepods, and the ctenophore **Beroë ovata** exhibited summer peaks in abundance.

No zooplankton studies have been conducted in West Bay or East Bay.

Benthos—Six benthic macroinvertebrate assemblages occur in the Galveston Bay complex, including open bay center, oyster reef, grassflat, bay margin, inlet-influenced and river-influenced assemblages (Table 2.4). The river-influenced assemblage covers the greatest area, including all of Trinity Bay, upper Galveston Bay, and part of East Bay. Oyster reef assemblages occur primarily in central Galveston Bay and divide Galveston Bay into upper and lower sections. Lower Galveston Bay contains primarily inlet-influenced and open bay center assemblages. The bay margin assemblage occurs on the bay side of Bolivar Peninsula and near Texas City. All six assemblages are found in West Bay.

The river-influenced assemblage contains a small group of common bay species, including the bivalve **Mulinia lateralis**, the polychaetes **Capitella capitata**, **Streblospio benedicti** and **Mediomastus** spp., and brackish-water mollusks such as **Macoma mitchelli**, **Texadina sphinctostoma** and **Rangia flexuosa**. These species occur in parts of estuaries where salinities vary from fresh to brackish over long periods of time. Average salinities in Trinity Bay range from less than 5 ppt to about 10 ppt (15). However, over relatively short periods of time, the river-influenced assemblage is subjected to greater natural salinity fluctuations (0-33 ppt) than are other bay assemblages.

In contrast to the river-influenced assemblage, the inlet-influenced assemblage contains the highest number of species, partly because of more stable salinities. This assemblage, composed primarily of mollusks, contains some species that are restricted to the area of Galveston and East Bays near Bolivar Roads and Rollover Pass and to West Bay near San Luis Pass. Common species include mollusks such as **Mulinia lateralis**, **Lyonsia hyalina**, **Mysella planulata**, **Turbonilla** sp., **Acteocina canaliculata** and **Nassarius acutus** and polychaetes such as **Owenia fusiformis**, **Paraprionospio pinnata**, **Clymenella torquata** and **Mediomastus californiensis**.

The oyster reef assemblage is found primarily on or near reefs and is dominated by the American oyster **Crassostrea virginica** and the mollusks **Ischadium recurvum**, **Brachidontes exustus** and **Mulinia lateralis**. The common polychaetes **Mediomastus californiensis** and **Streblospio benedicti** are also abundant.

The bay margin assemblage is limited to shallow, sandy stations in East and West Bays and lower Galveston Bay. Most stations are less than 2 km from shore and less than 1 meter deep. Crustaceans such as **Ampelisca** spp., **Cerapus tubularis** and **Oxyurostylis salinoi** are more abundant in the bay margin assemblage than in any other assemblage except the grassflat assemblage.

Crustaceans are dominant in the grassflat assemblage and include such species as **Ampelisca abdita**, **Acanthohaustorius** sp. and **Cymadusa compta**. Bivalves such as **Amygdalum papyrium**, **Lyonsia hyalina** and **Laevicardium mortoni** and polychaetes such as **Aricidea fragilis** and **Scoloplos fragilis** are common. Grassflats are of limited distribution in the Galveston Bay system and occur principally in patches along the margin of the Trinity River delta and Christmas Bay.

The open bay center assemblage occurs in lower Galveston Bay and East and West Bays in muddy sediments and in relatively deep water. Polychaetes are the predominant group and are characterized by **Paraprionospio pinnata**, **Parandalia fauveli** and **Podarkeopsis levifuscina**.

A 12-month study of the benthos of Trinity Bay (1) indicated that polychaetes were the most speciose group collected (35 species), followed by crustaceans (18 species), mollusks (14 species), and bryozoans, rhynchocoels and chordates (5 species). Seventy-four percent of all individuals collected were polychaetes, primarily **Mediomastus californiensis** and other capitellids. Other abundant species were the mollusks **Macoma** sp., **Amnicola** sp. and **Texadina sphinctostoma**. Densities of benthic organisms exhibited spring and late summer peaks.

Macroinvertebrates—These mobile and sessile species are rarely encountered using the plankton or benthic sampling methods involved in prior sections except as larval or early juvenile forms. No synoptic surveys of macroinvertebrates in the Galveston Bay system (other than oysters, **Crassostrea virginica**) have been conducted. The public oyster reefs within the estuary have been described (19, 20). The reefs are typically long and narrow, are oriented perpendicular to water currents, and are densest in the mid-bay region and across the mouth of East Bay. Settlement of spat (free-swimming larvae) generally occurs during April to November, primarily in the summer months. Oysters reach market size in 13 to 18 months. The distribution of oyster reefs depends on the interactions of temperature, salinity, predation and disease (19). High salinities allow an increased predation by oyster drills (**Thais haemastoma**) and increased infection by **Perkinsus marinus** ("dermo"). Extensive periods of low salinity can also kill oysters, so most of the viable reefs are located in areas characterized by 10 to 20 ppt mean annual salinity. Since 1975, the areal distribution of oyster reefs has been stable.

Although not well documented, there are numerous species of mobile macroinvertebrates in the estuary (13, 21-24) (Table 2.5). All of these species were collected in western West Bay (but are found elsewhere) and many of these species are probably limited to submerged vegetation or oyster reef habitats, rarely caught elsewhere. In shallow, fringing habitats **Palaemonetes** spp. (grass shrimp) are most common and reach maximum abundance in March through July. **Macrobrachium ohione**

Table. 2.4. Characteristic Species in Macroinvertebrate Assemblages (15).

Galveston-Trinity-East Bays

River-Influenced

Bivalves
- **Mulinia lateralis**
- **Macoma mitchelli**
- **Rangia flexuosa**

Gastropods
- **Texadina sphinctostoma**
- **Vioscalba louisianae**
- **Texadina barretti**

Polychaetes
- **Parandalia fauveli**
- **Streblospio benedicti**
- **Capitella capitata**
- **Mediomastus californiensis**
- **Polydora ligni**

Crustaceans
- **Corophium louisianum**

Inlet-Influenced

Bivalves
- **Mulinia lateralis**
- **Lyonsia hyalina floridana**
- **Tellina texana**

Gastropods
- **Turbonilla cf. T. interrupta**
- **Nassarius acutus**

Polychaetes
- **Owenia fusiformis**
- **Apoprionospio pygmaea**
- **Onuphis eremita oculata**

Bay Margin

Bivalves
- **Amygdalum papyrium**

Polychaetes
- **Streblospio benedicti**
- **Paraprionospio pinnata**
- **Tharyx marioni**
- **Owenia fusiformis**

Crustaceans
- **Oxyurostylis salinoi**
- **Monoculodes nyei**
- **Cerapus tubularis**
- **Hargeria rapax**

Open Bay Center

Bivalves
- **Mulinia lateralis**

Polychaetes
- **Paraprionospio pinnata**
- **Pseudeurythoe ambigua**
- **Parandalia fauveli**
- **Sigambra spp.**

Crustaceans
- **Acetes americanus**

Oyster Reef

Gastropods
- **Boonea impressa**
- **Texadina sphinctostoma**

Bivalves
- **Crassostrea virginica**
- **Ischadium recurvum**
- **Brachidontes exustus**
- **Mulinia lateralis**

Polychaetes
- **Nereis succinea**
- **Polydora ligni**
- **Mediomastus californiensis**
- **Streblospio benedicti**
- **Parandalia fauveli**

Crustaceans
- **Melita nitida**
- **Rhithropanopeus harrisii**
- **Cassidinidea lunifrons**

West Bay (including Chocolate, Christmas and Bastrop Bays)

Grassflat

Bivalves

Amygdalum papyrium
Laevicardium mortoni

Polychaetes

Chone duneri
Nereis succinea
Streblospio benedicti

Crustaceans

Ampelisca abdita
Edotea montosa
Cerapus tubularis
Listriella sp.

Oyster Reef

Bivalves

Crassostrea virginica
Ischadium recurvum

Polychaetes

Nereis succinea

Crustaceans

Grandidierella bonnieroides
Oxyurostylis salinoi
Rhithropanopeus harrisii

River-Influenced

Gastropods

Texadina barretti

Bivalves

Macoma mitchelli
Mulinia lateralis

Polychaetes

Parandalia fauveli
Scoloplos fragilis
Paraprionospio pinnata
Glycinde solitaria

Open Bay Center

Bivalves

Mulinia lateralis
Mysella planulata
Lyonsia hyalina floridana

Polychaetes

Paraprionospio pinnata
Podarkeopsis levifuscina
Cossura delta
Mediomastus californiensis
Melinna maculata

Inlet-Influenced

Gastropods

Turbonilla cf. T. interrupta
Acteocina canaliculata

Bivalves

Mulinia lateralis
Periploma margaritaceum
Mysella planulata
Lyonsia hyalina floridana

Polychaetes

Paraprionospio pinnata
Clymenella torquata
Owenia fusiformis
Mediomastus californiensis

Crustaceans

Ampelisca brevisimulata

Bay Margin

Gastropods

Acteocina canaliculata
Acteon punctostriatus

Bivalves

Mulinia lateralis
Ensis minor
Lyonsia hyalina floridana

Polychaetes

Mediomastus californiensis

Crustaceans

Ampelisca abdita
Ampelisca brevisimulata
Oxyurostylis salinoi

Table 2.5. Macrocrustaceans Collected in Trawl Surveys of the Galveston Bay System (13, 21-23).

<u>Stomatopods</u>	<u>Crabs</u>
Squilla empusa	Petrolisthes armatus
	Clibanarius vittatus
<u>Shrimp</u>	Pagurus longicarpus
Penaeus setiferus	Pagurus pollicaris
Penaeus aztecus	Ovalipes stephensoni
Penaeus duorarum	Callinectes sapidus
Trachypenaeus similis	Callinectes similis
Xiphopenaeus kroyeri	Menippe mercenaria
Alpheus heterochaelis	Rhithropanopeus harrisii
Palaemonetes pugio	Hexapanopeus angustifrons
Palaemonetes vulgaris	Neopanope texana
Palaemonetes intermedius	Eurypanopeus depressus
Macrobrachium ohione	Panopeus herbstii
Periclimenes longicaudatus	Pachygrapsus transversus
Hippolyte zostericola	Uca spp.
Tozeuma carolinense	Libinia dubia
	Heterocrypta granulata

Table 2.6. Comparison of the Most Numerous Fishes Collected During a Two-Year Period in Various Galveston Bay Habitats (Rank Order) (27).

<u>Channels</u>	<u>Open Bay</u>
Stellifer lanceolatus	Micropogonias undulatus
Micropogonias undulatus	Anchoa mitchilli
Symphurus plagiusa	Cynoscion arenarius
Anchoa mitchilli	Stellifer lanceolatus
Polydactylus octonemus	Arius felis
Arius felis	Sphoeroides parvus
Menticirrhus americanus	Citharichthys spilopterus
Brevoortia patronus	Leiostomus xanthurus
Citharichthys spilopterus	Symphurus plagiusa
Leiostomus xanthurus	Polydactylus octonemus
<u>Nearshore Flats</u>	<u>Peripheral Lagoons and Bayous</u>
Micropogonias undulatus	Micropogonias undulatus
Anchoa mitchilli	Anchoa mitchilli
Leiostomus xanthurus	Leiostomus xanthurus
Arius felis	Cynoscion arenarius
Sphoeroides parvus	Mugil cephalus
Brevoortia patronus	Citharichthys spilopterus
Cynoscion arenarius	Brevoortia patronus
Citharichthys spilopterus	Arius felis
Menticirrhus americanus	Symphurus plagiusa
Stellifer lanceolatus	Sphoeroides parvus

(river shrimp) is found in low salinity areas during April and May. Postlarval **Penaeus aztecus** (brown shrimp) enter the estuary in February through April, move into shallow nurseries, and then reappear in large numbers in open bay waters during March through July. **Penaeus setiferus** (white shrimp) postlarvae begin entering the estuary in April and juveniles become most numerous in open waters during July through November. A small population of **Penaeus duorarum** (pink shrimp) enters as larvae to shallow estuarine nurseries in the fall and juveniles are recaptured in March through May in open bay waters. **Callinectes sapidus** (blue crab) is most susceptible to sampling gear in October through April but may recruit almost all year. One species not included in Table 2.5 but quite important to the system is **Lolliguncula brevis** (brief squid). It is a summer inhabitant of higher salinity waters (9) and may be an important determinant of community composition as a predator (25).

Vertebrates

This section encompasses fishes, birds, amphibians, reptiles and mammals, but only fishes have been the object of synoptic surveys.

Fishes—A comprehensive list of the ichthyofauna of the Galveston Bay system encompassed 66 families, 122 genera and 162 species (26). Freshwater fishes (9 families, 19 species) rarely found in the bay were included. Results of a two-year, synoptic trawl survey (27) indicated that, of 96 species recorded, six species accounted for 91 percent of the total number of fishes collected: **Micropogonias undulatus** (Atlantic croaker, 51 percent); **Anchoa mitchilli** (bay anchovy, 22 percent); **Stellifer lanceolatus** (star drum, 8 percent); **Leiostomus xanthurus** (spot, 4 percent); **Cynoscion arenarius** (sand seatrout, 3 percent); and **Arius felis** (hardhead catfish, 3 percent). These six species plus **Mugil cephalus** (striped mullet) were responsible for 74 percent of the biomass collected, dominated by **Micropogonias** (37 percent of the weight) over all others (<10 percent each). In general, the same small group of 13 species dominated catches in various bay habitats (Table 2.6). The total fish fauna was most numerous in April and May (dominated by **Micropogonias**) and least dense in December and January (dominated by **Anchoa**). Biomass peaks generally occurred May through August (**Micropogonias, Stellifer**), while the biomass of a mixed assemblage was lowest in November. Although no surveys have addressed West Bay proper, surveys of Chocolate Bayou (24) and Christmas Bay (13) revealed 72 and 83 species of fishes, respectively, with similar dominant species.

Larval and postlarval fishes often numerically dominate zooplankton collections. The same species that later comprise the bulk of the trawl catches are usually the most abundant as plankters (17, 18, 28).

Birds—Although no comprehensive study of the avifauna of the Galveston Bay system has been conducted, observers and checklists have recorded 139 bird species associated with wetlands and bay habitats (29, 30). This group of species accounts for 25 percent of the 565 bird species recorded for Texas (31). Further, these wetland-related forms do not include the large number of terrestrial resident or migratory birds. Three large groups of birds have a significant representation in the Galveston Bay system—waterfowl, shorebirds and colonial nesting waterbirds.

Waterfowl are censused each January during the Mid-winter Waterfowl Survey, a cooperative effort between the Texas Parks and Wildlife Department and the U.S. Fish and Wildlife Service. These surveys have shown that 60 percent of Texas' wintering waterfowl are found on the upper Texas coast, including large populations of **Chen caerulescens** (snow goose), associated with rice-growing regions of the coastal prairies (32). Aerial surveys of the Galveston Bay system for the years 1978 and 1984 through 1987 have recorded an average of 11,500 waterfowl annually. The five most common species observed during these surveys were **Anas crecca** (green-winged teal), **Aythya collaris** (ring-necked duck), **Aythya affinis** (lesser scaup), **Mergus serrator** (red-breasted merganser), and **Oxyura jamaicensis** (ruddy duck). Although a total of 32 species of waterfowl has been observed in the bay system (Table 2.7), only **Dendrocygna bicolor** (fulvous whistling duck), **Anas fulvigula** (mottled duck), **Aix sponsa** (wood duck), and **Anas discors** (blue-winged teal) are regular breeders in the area. The remaining species of waterfowl use the estuary during migration or while overwintering.

The Galveston Bay system has been identified by the Western Hemisphere Shorebird Reserve Network as a regionally significant reserve site (34), denoting support of >5 percent of all mid-continental shorebird populations during migration. Large populations of migrating or overwinter-

Table 2.7. Waterfowl Observed in the Galveston Bay System (32, 33).

Common Name	Scientific Name	Common Name	Scientific Name
Fulvous whistling duck	Dendrocygna bicolor	American wigeon	Anas americana
Black-bellied whistling duck	Dendrocygna autumnalis	Canvasback	Aythya valisineria
Greater white-fronted goose	Anser albifrons	Redhead	Aythya americana
Snow goose	Chen caerulescens	Ring-necked duck	Aythya collaris
Ross' goose	Chen rossii	Greater scaup	Aythya marila
Canada goose	Branta canadensis	Lesser scaup	Aythya affinis
Wood duck	Aix sponsa	Old squaw	Clangula hyemalis
Green-winged teal	Anas crecca	Black scoter	Melanitta nigra
Mottled duck	Anas fulvigula	Surf scoter	Melanitta perspicillata
Mallard	Anas platyrhynchos	White-winged scoter	Melanitta fusca
Northern pintail	Anas acuta	Common goldeneye	Bucephala clangula
Blue-winged teal	Anas discors	Bufflehead	Bucephala albeola
Cinnamon teal	Anas cyanoptera	Hooded merganser	Lophodytes cucullatus
Northern shoveler	Anas clypeata	Red-breasted merganser	Mergus serrator
Gadwall	Anas strepera	Ruddy duck	Oxyura jamaicensis
		Masked duck	Oxyura dominica

Table 2.8. Shorebirds Recorded for the Galveston Bay System (33, 34).

Common Name	Scientific Name	Common Name	Scientific Name
Black-bellied plover	Pluvialis squatarola	Long-billed curlew	Numenius americanus
Lesser golden-plover	Pluvialis dominica	Marbled godwit	Limosa fedoa
Snowy plover	Charadrius alexandrinus	Hudsonian godwit	Limosa haemastica
Wilson's plover	Charadrius wilsonia	Ruddy turnstone	Arenaria interpres
Semipalmated plover	Charadrius semipalmatus	Red knot	Calidris canutus
Piping plover	Charadius melodus	Sanderling	Calidris alba
Killdeer	Charadrius vociferus	Semipalmatedsandpiper	Calidris pusilla
American oyster-catcher	Haematopus palliatus	Western sandpiper	Calidris mauri
Black-necked stilt	Himantopus mexicanus	Least sandpiper	Calidris minutilla
American avocet	Recurvirostra americana	White-rumped sandpiper	Calidris fuscicollis
Greater yellowlegs	Tringa melanoleuca	Baird's sandpiper	Calidris bairdii
Lesser yellowlegs	Tringa flavipes	Pectoral sandpiper	Calidris melanotos
Solitary sandpiper	Tringa solitaria	Dunlin	Calidris alpina
Willet	Catoptrophorus semipalmatus	Stilt sandpiper	Calidris himantopus
Spotted sandpiper	Actitis macularia	Buff-breasted sandpiper	Tryngitis subruficollis
Upland sandpiper	Bartramia longicauda	Short-billed dowitcher	Limnodromus griseus
Eskimo curlew	Numenius borealis	Long-billed dowitcher	Limnodromus scolopaceus
Whimbrel	Numenius phaeopus	Common snipe	Gallinago gallinago
		American woodcock	Scolopax minor
		Wilson's phalarope	Phalaropus tricolor
		Red-necked phalarope	Phalaropus lobatus
		Red phalarope	Phalaropus fulicaria

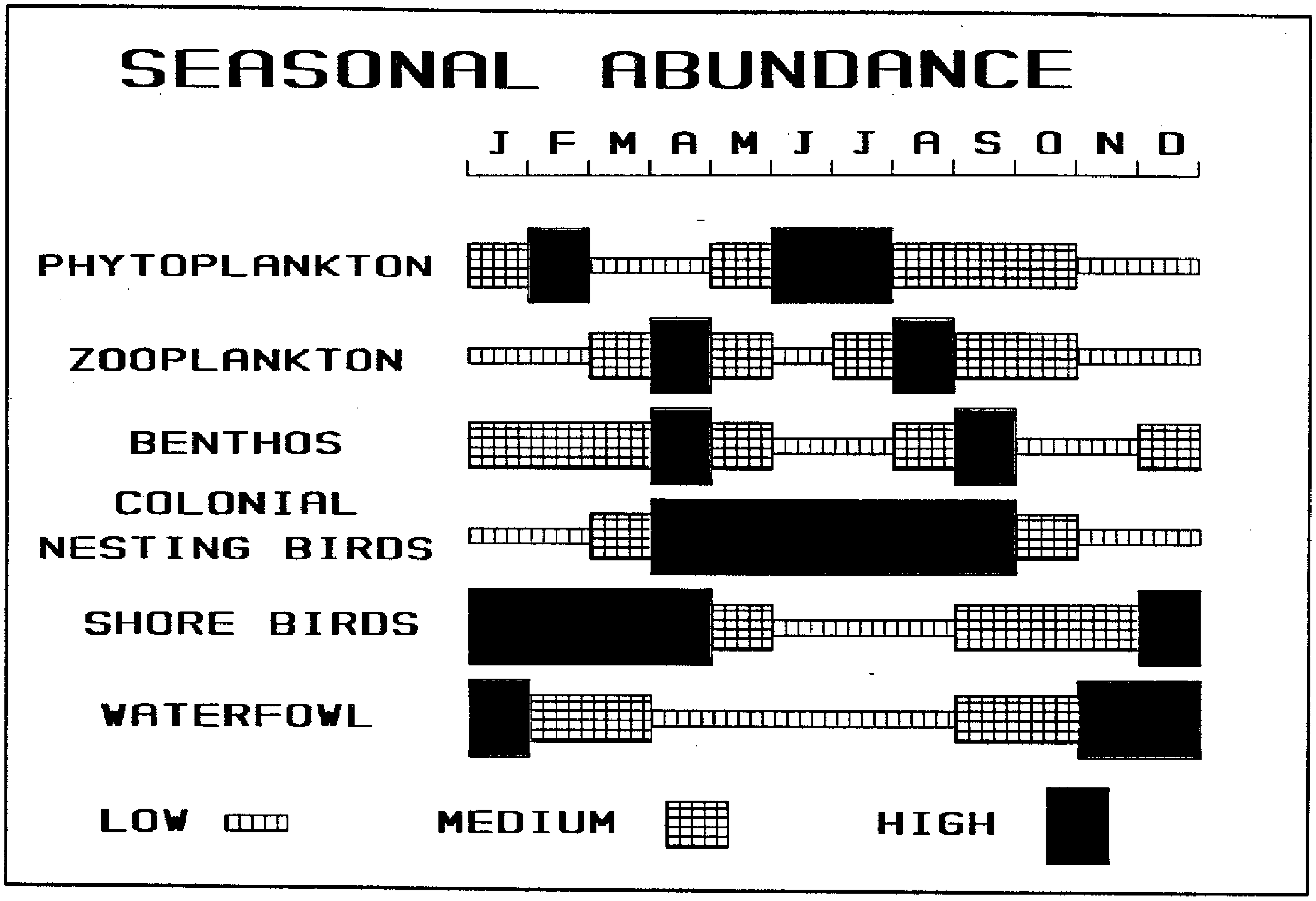

Figure 2.1. Seasonality of the components of the benthic food web in relation to the abundance of Galveston Bay avifauna (1, 17, 33, 34, 35, 36, 64).

ing shorebirds utilize intertidal flats on Bolivar Peninsula and on the east and west ends of Galveston Island. Of the 35 species of shorebirds reported for Galveston Bay (Table 2.8), the most common forms are **Pluvialis squatarola** (black-bellied plover), **Recurvirostra americana** (American avocet), **Catoptrophorus semipalmatus** (willet), **Calidris alba** (sanderling), **Calidris mauri** (western sandpiper), **Calidris alpina** (dunlin), and **Limnodromus** spp. (dowitchers) (64). Peaks in shorebird utilization of Galveston Bay occur during the winter months through spring migration (December through May). Chronology of migration and intertidal flat use may be tied to macrobenthic prey phenology (Figure 2.1). Six species of shorebirds are known to nest in the bay complex: **Charadrius wilsonia** (Wilson's plover), **Charadrius vociferus** (killdeer), **Haematopus palliatus** (American oystercatcher), **Himantopus mexicanus** (black-necked stilt), willet and American avocet.

Surveys of colonial nesting waterbirds in the Galveston Bay system have been conducted since 1967 (33, 35). During the period 1973 through 1987 (Figure 2.2), numbers of pairs of colonial nesting waterbirds varied from lows of approximately 39,000 in 1978 and 1985 to a high of 71,700 in 1982 with a mean of 52,136 (33). Active colony numbers have increased from 20 in 1973 to 42 in 1987. Colony sites include gravel and shell bars, **Spartina alterniflora** marshes, cypress stands, dredged material islands, and industrial and developed locations. Twenty-two species of colonial nesting waterbirds have been reported as nesting during the 21 years of surveys (Table 2.9). The three most common species during the 1986 nesting season were **Larus atricilla** (laughing gull), **Sterna maxima** (royal tern) and **Bubulcus ibis** (cattle egret) (36).

Birds that have been identified as threatened or endangered by the U.S. Fish and Wildlife Service (33) include **Pelecanus occidentalis** (brown pelican), **Charadrius melodus** (piping plover), **Numenius borealis** (eskimo curlew), **Sterna antillarum** (interior least tern), **Haliaeetus leucocephalus** (bald eagle), **Falco peregrinus** (peregrine falcon), and **Mycteria americana** (wood stork).

Amphibians and Reptiles—Ninety-two species of amphibians and reptiles have been reported for the four counties surrounding Galveston Bay (37). Mueller (38) described only 15 species of amphibians and reptiles from nontidal wetlands on Galveston Island, however. The American

Table 2.9. Colonial Nesting Waterbirds of the Galveston Bay System (36).

Common Name	Scientific Name	Common Name	Scientific Name
Olivaceous cormorant	**Phalacrocorax olivaceus**	White ibis	**Eudocimus albus**
Anhinga	**Anhinga anhinga**	White-faced ibis	**Plegadis chihi**
Great blue heron	**Ardea herodias**	Roseate spoonbill	**Ajaia ajaja**
Great egret	**Casmerodias albus**	Laughing gull	**Larus atricilla**
Snowy egret	**Egretta thula**	Gull-billed tern	**Sterna nilotica**
Little blue heron	**Egretta caerulea**	Caspian tern	**Sterna caspia**
Tricolored heron	**Egretta tricolor**	Royal tern	**Sterna maxima**
Reddish egret	**Egretta rufescens**	Sandwich tern	**Sterna sandvicensis**
Cattle egret	**Bubulcus ibis**	Forster's tern	**Sterna forsteri**
Black-crowned night-heron	**Nycticorax nycticorax**	Least tern	**Sterna antillarum**
Yellow-crowned night-heron	**Nycticorax violaceus**	Black skimmer	**Rynchops niger**

Table 2.10. Game and Furbearing Mammals of the Four Counties Surrounding Galveston Bay (41, 42).

Common Name	Scientific Name	Common Name	Scientific Name
White-tailed deer	**Odocoileus virginianus**	Red fox	**Vulpes vulpes**
Virginia opossum	**Didelphis virginiana**	Gray fox	**Urocyon cinereoargenteus**
Beaver	**Castor canadensis**	Long-tailed weasel	**Mustela frenata**
Muskrat	**Ondatra zibethicus**	Mink	**Mustela vison**
Nutria	**Myocaster coypus**	Eastern spotted skunk	**Spilogale putorius**
Raccoon	**Procyon lotor**	Striped skunk	**Mephitis mephitis**
Ringtail	**Bassariscus astutus**	River otter	**Lutra canadensis**
Coyote	**Canis latrans**	Bobcat	**Felis rufus**

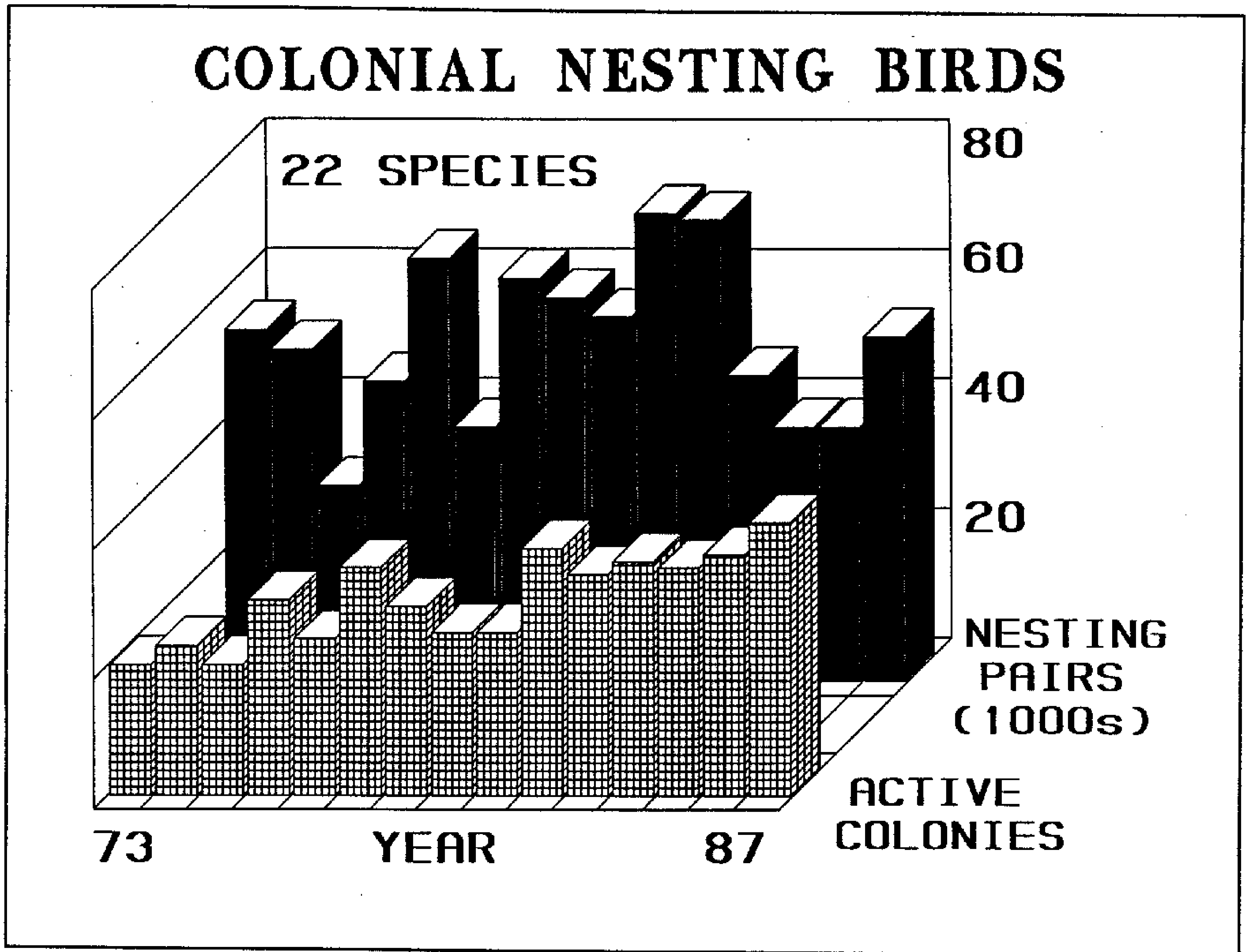

Figure 2.2. Abundance of colonial nesting birds during 1973-1987 (33, 35).

alligator (**Alligator mississippiensis**) has recently become a harvestable animal under state statutes (39). During 1984-1986, a total of 655 alligators were harvested from the counties surrounding the estuary, with 384 (59 percent) taken in freshwater marshes of Chambers County.

Reptiles that frequent the system and have been identified as threatened or endangered by the U.S. Fish and Wildlife Service (33) include: **Dermochelys coriacea** (leatherback sea turtle), **Lepidochelys kempi** (Kemp's ridley sea turtle), **Caretta caretta** (loggerhead sea turtle) and **Chelonia mydas** (green sea turtle). Sea turtles were once an important component of the bay system, so much so that there was a commercial sea turtle fishery in Galveston Bay during the 1890's (40).

Mammals—Schmidly (41, 42) documents 54 species of mammals for the counties surrounding Galveston Bay. Of these, 15 are furbearers and one is a game species (Table 2.10). The mammals most dependent upon wetlands environments include **Sylvilagus aquaticus** (swamp rabbit), **Sciurus carolinensis** (gray squirrel), **Castor canadensis** (beaver), **Ondatra zibethicus** (muskrat), **Rattus rattus** (roof rat), **Oryzomys palustris** (northern rice rat), **Myocastor coypus** (nutria), **Procyon lotor** (raccoon), **Mustela vison** (mink), **Lutra canadensis** (river otter), and **Tursiops truncatus** (bottlenosed dolphin).

Dynamics and Interactions

Some of the relationships of organisms to their physical environments were considered previously, but the interactions of groups of organisms with extrinsic factors such as temperature, salinity, substrate and habitat availability need to be emphasized. This section will generally follow the trophic structure of the estuary.

Primary Productivity

The relative contribution of each floral component to total system primary production has been

Table 2.11. Primary Productivity in the Galveston Bay System (Data Sources in Parentheses).

Flora	Average Estimated Primary Productivity (g dry/m²/yr)	Areal Coverage (km²)	Estimated Annual Production (metric tons)
Phytoplankton (44,45,47)	350	1,425	498,750
Benthic microflora (44,47)	500	1,425	712,500
Submerged vegetation (1,15,48)	2,600	1	2,600
Freshwater marsh (1,12)	820	40	32,800
Salt-Brackish Marsh (12,43)	1,100	370	407,000
Woodlands/swamps (12,47)	700	500	350,000

roughly estimated in Table 2.11. Phytoplankton, benthic microflora, salt and brackish marshes, and woodlands and swamps each contribute roughly the same order of magnitude of organic materials to annual production. Fresh marshes produce an order of magnitude less, while seagrasses contribute two orders of magnitude less production than the four main components. Some of the assumptions made in constructing Table 2.11 need testing, such as productivity of phytoplankton and benthic microflora within Galveston Bay and presumption that such productivity occurs under the total bay surface of 1,425 km² (550 mi²). Within the various habitats, the variation in productivity can be dramatic. For example, in the fresh marsh **Sagittaria graminea** produces 215 g dry/m²/year while **Phragmites australis** produces 2,984 g dry/m²/year (1), and in the salt marsh **Batis maritima** produces 425 g dry/m²/year while Spartina spp. produce 1,100 g dry/m²/year (43). The most productive component, the seagrasses, are the least abundant in this estuary.

Most of the plant production is separated in space and time from the consumer community. In fact, some of that production may never reach the consumers due to inundated regimes and tissue storage. It has been estimated that woodlands, swamps and freshwater marshes export only 8 to 10 percent of the annual aboveground production whereas the frequently inundation low salt marshes may export 30 to 45 percent annually (1, 47). The low nutritional quality, refractory nature of much of the biomass, and resistance to direct grazing all increase from phytoplankton and algae through submerged aquatic vegetation to emergent vascular plants of the salt marsh and woodlands. Thus, the primary consumption of most of the plant biomass is only available along the detritus pathway. Although many organisms play major roles in breaking down this refractory material, they rarely directly assimilate the organic plant matter and, instead, utilize the surface microbial decomposers (47).

Primary Consumption

Less than 10 percent of emergent vegetation of these wetlands is consumed directly, and most of the grazers are insects (47). **Ondatra zibethicus** (muskrat) and **Myocastor coypus** (nutria) are other direct consumers. Submerged vegetation may be directly consumed by a small number of aquatic organisms (snails, fishes such as **Lagodon rhomboides** [pinfish]) as well as certain species of ducks. Phytoplankton are directly grazed by many zooplankters and planktivorous fishes, while benthic algae and epiphytes are utilized by snails, fiddler crabs and other organisms (47). The vast majority of primary consumers in the system are detritivores, species that directly or indirectly consume detrital particles and, lacking the necessary digestive enzymes, in reality utilize only the surface bacteria and fungi. This group includes many benthic organisms (bivalves, gastropods, crustaceans) and bottom feeding fishes and macroinvertebrates (47).

The available evidence suggests that the phytoplankton-based branch of the food web may not be as important to the Galveston Bay system as is the emergent marsh-detritus branch, even though annual primary production may be similar for both groups. First, average phytoplankton densities are on the low end of the scale for Texas estuaries (1), which are, in turn, on the low end of the range of estuarine production in general (44). Second, zooplankton densities (the main consumers of phytoplankton) are also on the low end of the ranges seen in other Texas estuaries (1). Third, salt marsh productivity is higher in Texas than in most other Atlantic and Gulf coast states (63). Finally, the macrobenthic and fish faunas are omnivores or carnivores except in their earliest larval stages (47).

Habitat Utilization

Vegetated habitats serve other functions than providing direct or indirect sources of food. Aside from these, wetlands function as natural water treatment plants for nutrients and wastes, provide aesthetic value, control biogeochemical cycles of elements such as nitrogen and sulphur, buffer inlands from storms and reduce flooding, and provide useful products such as lumber. Perhaps the most significant functions of wetlands for estuarine organisms are provision of nursery areas for feeding, refuge and substrate utilization by other organisms. In a **Spartina alterniflora** marsh, densities of crustaceans such as **Palaemonetes pugio, Callinectes sapidus** and **Penaeus aztecus** and fishes such as **Lagodon rhomboides, Fundulus** spp., **Sciaenops ocellatus** and **Cynoscion nebulosus** were all significantly higher in flooded marsh areas than in adjacent non-vegetated waters (23, 49). During most seasons, densities of juveniles of many commercially, recreationally and ecologically important fishes and crustaceans are higher in vegetated habitats such as salt marshes, fresh marshes and seagrasses around Galveston Bay than in adjacent open waters (Figure 2.3, from 50). There are indications that the vegetative structure provides refuge from predators and foods (such as epiphytic algae and high densities of infauna) not found in open waters (50-52). The connection between amounts of vegetated habitats and fisheries productivity in adjacent waters has been demonstrated worldwide. For example, landings of brown shrimp in nearshore Louisiana waters have been directly linked to the amount of salt marsh vegetation present (53). Thus, wetlands habitats are quite valuable in many aspects.

Fisheries

The Galveston Bay system supports a wide variety of species in its bay and nearshore commercial and recreational fisheries (Table 2.12). In 1986, commercial fisheries landed more than 10,000 metric tons of seafood with a dockside value exceeding $26 million for the top 10 species alone (Table 2.13). The commercial catches were dominated by invertebrates such as brown shrimp, pink shrimp and white shrimp (totaling 6.8 million kilograms), blue crabs (1.4 million kilograms) and oysters (1.6 million kilograms, whole) (54). Southern and gulf flounders and Atlantic croaker were the dominant finfishes. The 1986 recreational fisheries landed in excess of 280 tons, primarily of sportfishes such as spotted seatrout, sand seatrout, southern and gulf flounders, Atlantic croaker and redfish (55).

Since 1960, landings of penaeid shrimp, oysters and blue crabs have been relatively stable given some degree of annual fluctuation (Figure 2.4) (54, 56). Some abrupt changes have been due to regulatory actions such as closing of bays to oyster harvesting after heavy rainfall and pollutant loading. An apparent upward trend in shrimp landings is in part due to increasing inshore fishing effort but may also indicate increasing marsh access (discussed later). Fluctuations in finfish landings since 1975 (Figure 2.5) (54, 55) were primarily due to regulatory actions in the face of heavy commercial and recreational fishing pressure on spotted seatrout (**Cynoscion nebulosus**) and redfish (**Sciaenops ocellatus**) in the late 1970's. Commercial landings of spotted seatrout and redfish were banned, thus the decline seen around 1980. The commercial fishery is now increasing, with flounders the dominant species and mullets, Atlantic croaker, black drum and sheepshead next in importance. Recreational fishing, now controlled by size and bag limits on certain species, has stabilized and is led by landings of spotted seatrout followed by sand seatrout, redfish, flounders and Atlantic croaker.

A synopsis of commercial and recreational fisheries (Figure 2.6) indicates that landings are generally highest in summer and fall months, with the exception of oysters that are a winter-spring harvest with public reefs closed during the warm months. The blue crab fishery reaches a maximum in early summer. The bait shrimp fishery is most productive in summer and fall, coincidently when both demand and supply are highest. The bay commercial shrimp fishery has two seasons separated by closures: a June and July fishery for brown shrimp (**Penaeus aztecus**) and an August through

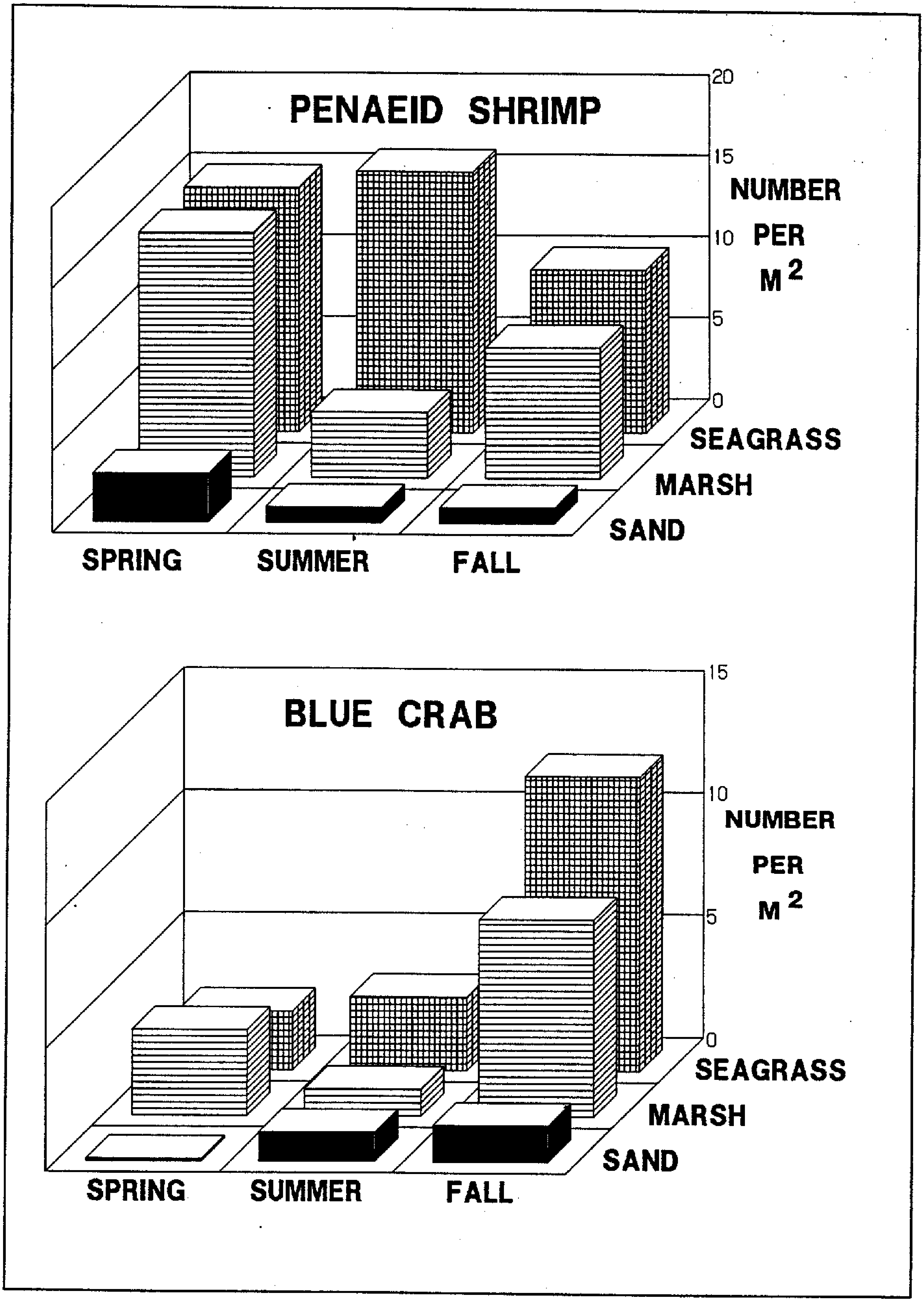

*Figure 2.3. Habitat selection by penaeid shrimp (Penaeus spp.) and blue crabs (**Callinectes sapidus**) in various aquatic habitats of the Galveston Bay estuary (50).*

Table 2.12. List of Common and Scientific Names of Commercial and Recreational Finfish and Shellfish Caught or Landed in Texas (54, 55).

Common Name	Scientific Name
Finfish	
African pompano	Alectis alaiis
Alligator gar	Lepisosteus spatula
Atlantic croaker	Micropogonias undulatus
Atlantic cutlassfish	Trichiurus lepturus
Atlantic moonfish	Selene setapinnis
Atlantic needlefish	Strongylura marina
Atlantic spadefish	Chaetodipterus faber
Atlantic stingray	Dasyatis sabina
Black drum	Pogonias cromis
Bluefish	Pomatomus saltatrix
Blue catfish	Ictalurus furcatus
Channel catfish	Ictalurus punctatus
Cobia	Rachycentron canadum
Codfish	Family Gadidae
Dolphin	Coryphaena hippurus
Flounder	
Gulf flounder	Paralichthys albigutta
Southern flounder	Paralichthys lethostigma
Florida pompano	Trachinotus carolinus
Freshwater drum	Aplodinotus gruniens
Gafftopsail catfish	Bagre marinus
Greater amberjack	Seriola dumerilli
Grouper	
Black grouper	Mycteroperca bonaci
Jewfish	Epinephelus itajara
Nassau grouper	Epinephelus striatus
Scamp	Mycteroperca phenax
Warsaw grouper	Epinephelus nigritus
Yellowedge grouper	Epinephelus flavolimbatus
Yellowfin grouper	Mycteroperca venenosa
Yellowmouth grouper	Mycteroperca interstitialis
Gulf butterfish	Peprilus burti
Hardhead catfish	Arius felis
Kingfish	
Gulf kingfish	Menticirrhus littoralis
Southern kingfish	Menticirrhus americanus
Ladyfish	Elops saurus
Largemouth bass	Micropterus salmoides
Little tunny	Euthynnus alletteratus
Mackerel	
King mackerel	Scomberomorus cavalla
Spanish mackerel	Scomberomorus maculatus
Menhaden	Brevoortia patronus
Mullet	
Striped mullet	Mugil cephalus
White mullet	Mugil curema
Ocellated flounder	Ancylopsetta quadrocellata
Permit	Trachinotus falcatus

Table 2.12. (Continued)

Common Name	Scientific Name
Pigfish	Orthopristis chrysoptera
Pinfish	Lagodon rhomboides
Red drum	Sciaenops ocellatus
Seatrout	
Sand seatrout	Cynoscion arenarius
Silver seatrout	Cynoscion nothus
Spotted seatrout	Cynoscion nebulosus
Shark	
Atlantic sharpnose	Rhizoprionodon terraenovae
Blacktip	Carcharhinus limbatus
Bull	Carcharhinus leucas
Great hammerhead	Sphyrna mokarran
Scalloped hammerhead	Sphyrna lewini
Shortfin mako	Isurus oxyrinchus
Smooth dogfish	Mustelis canis
Sheepshead	Archosargus probatocephalus
Silver perch	Bairdiella chrysoura
Smallmouth buffalo	Ictiobus bubalus
Smooth puffer	Lagocephalus laevigatus
Snapper	
Lane snapper	Lutjanus synagris
Red snapper	Lutjanus campechanus
Vermilion snapper	Rhomboplites aurorubens
Southern stingray	Dasyatis americanus
Spot	Leiostomus xanthurus
Striped burrfish	Chilomycterus schoepfi
Swordfish	Xiphias gladius
Tilefish	Lopholatilus chameleonticeps
Triggerfish, gray	Balistes capriscus
Tripletail	Lobotes surinamensis
Tuna	
Blackfin tuna	Thunnus atlanticus
Bluefin tuna	Thunnus thynnus
Yellowfin tuna	Thunnus albacares
Wahoo	Acanthocybium solanderi
Shellfish	
Atlantic bay scallop	Argopecten irradians
Crab	
Blue crab	Callinectes sapidus
Stone crab	Menippe mercenaria
American oyster	Crassostrea virginica
Shrimp	
Brown shrimp	Penaeus aztecus
White shrimp	Penaeus setiferus
Pink shrimp	Penaeus duorarum
Rock shrimp	Sicyonia brevirostris
Royal red shrimp	Hymenopenaeus robustus
Seabob	Xiphopenaeus kroyeri
Squid	
Brief squid	Lolliguncula brevis
Long-finned squid	Loligo pealei

Table 2.13. Landings by Galveston Bay Fisheries During 1986, Including Bay and Nearshore Waters (NMFS Statistical Subarea 18). Landings (Kilograms, kg) and Ex-vessel Value ($) Are in Thousands. ? = Ex-vessel Value Not Available (54, 56).

	Commercial		Recreational	
	Kg	$	Kg	$
Flounder	73	157	39	52
Atlantic croaker	18	9	37	11
Spotted seatrout	-	-	102	?
Sand seatrout	-	-	57	?
Redfish	-	-	43	?
Oysters	1,610	6,950	?	?
Blue crabs	1,375	1,043	?	?
Shrimp (3 species)	6,820	18,135	?	?

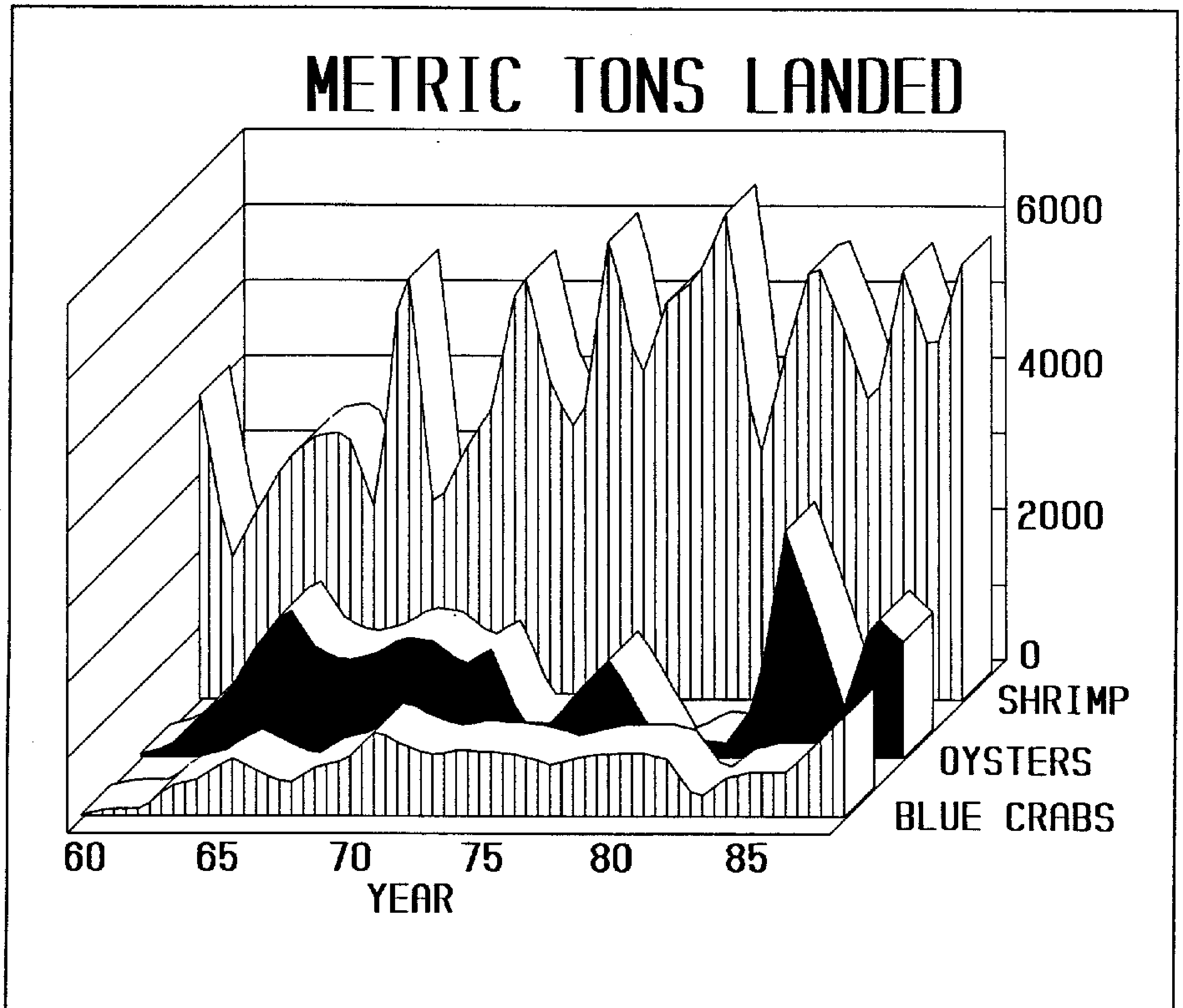

Figure 2.4. Annual landings (1960-1986) of blue crabs, oysters and three species of penaeid shrimp from Galveston Bay and nearshore waters (54, 56).

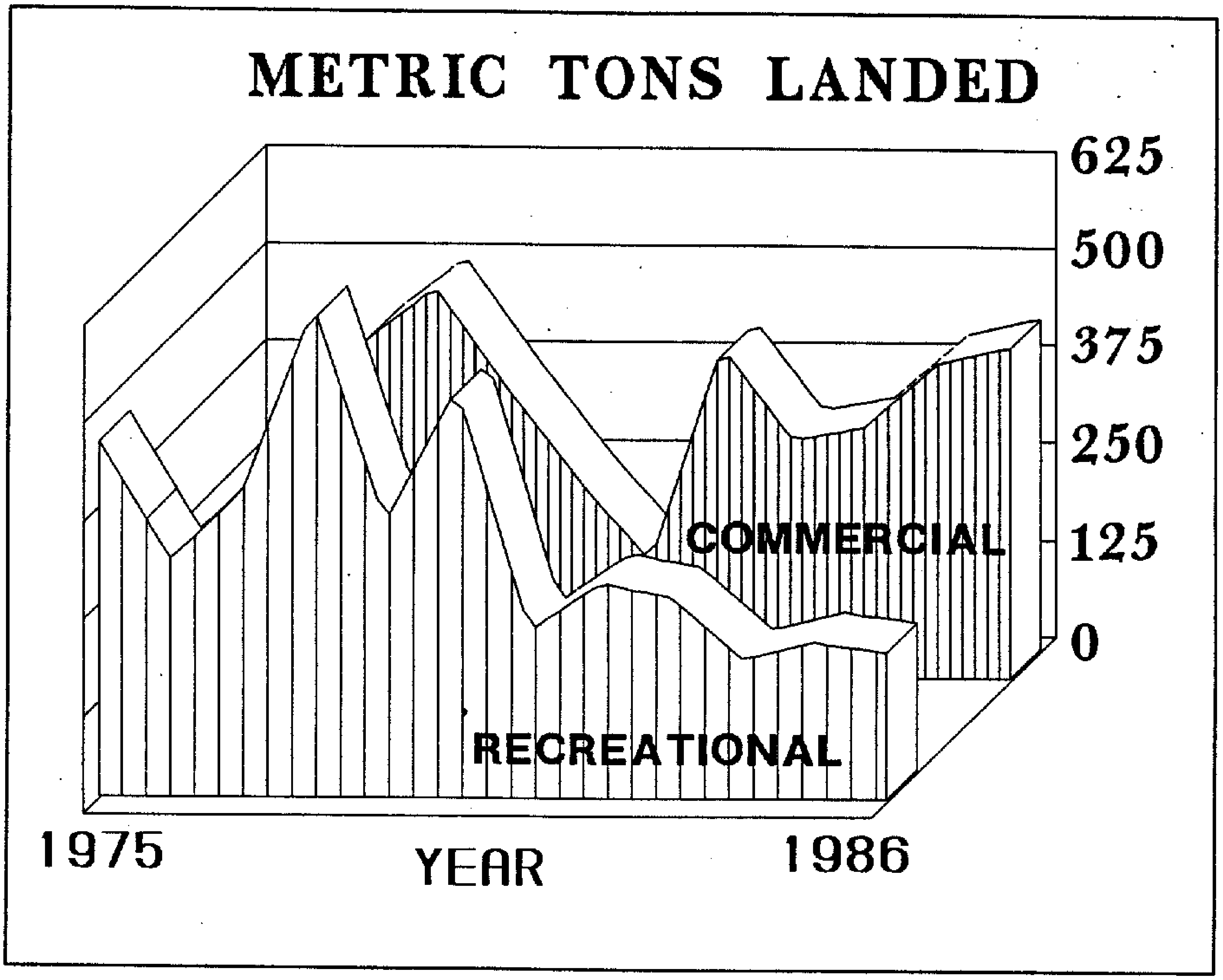

Figure 2.5. Annual landings (1975-1986) of commercial and recreational finfishes from Galveston Bay and nearshore waters (54, 56).

October fishery for white shrimp (P. setiferus). Recreational finfish fisheries are most productive in summer (spotted seatrout, redfish) and fall (flounder). Commercial finfish harvests are highest in the fall, concentrating on flounder, mullet and Atlantic croaker.

Ecological Interactions and Problems

The greatest problems involved in the maintenance of the Galveston Bay biota are related to human utilization of estuarine resources such as wetlands, fresh water and coastal habitats. Each of these areas presents its own unique interactions and prospects for various scenarios of the future status of the bay.

Sea Level Rise and Wetlands Loss

One of the critical problems facing the Galveston Bay estuary is apparent sea level rise (a combination of rapid, local subsidence of land due to groundwater and petroleum withdrawal (15) and slow, oceanic water rise from glacial melting) and associated wetlands loss. As pointed out in previous sections, many estuarine inhabitants depend on wetlands for food, refuge or living space. In 1979, the area containing the estuary's wetlands had elevations of 0 to 1.6 meters above mean sea level and encompassed some 740 square kilometers (Figure 2.7) (15).

The result of the combined forces of subsidence and glacial melting has led to a moderate projection of a 1.0- to 1.6-meter sea level rise by the year 2100 (57). If a 1.6-meter rise were experienced, the new wetlands area (0- to 1.6-meter elevations) would decrease in size by more than 50 percent to 360 square kilometers (Figure 2.8), assuming inland migration of the vegetation. The old 0- to 1.6-meter elevations would be converted to open bay water. However, this new wetlands area is

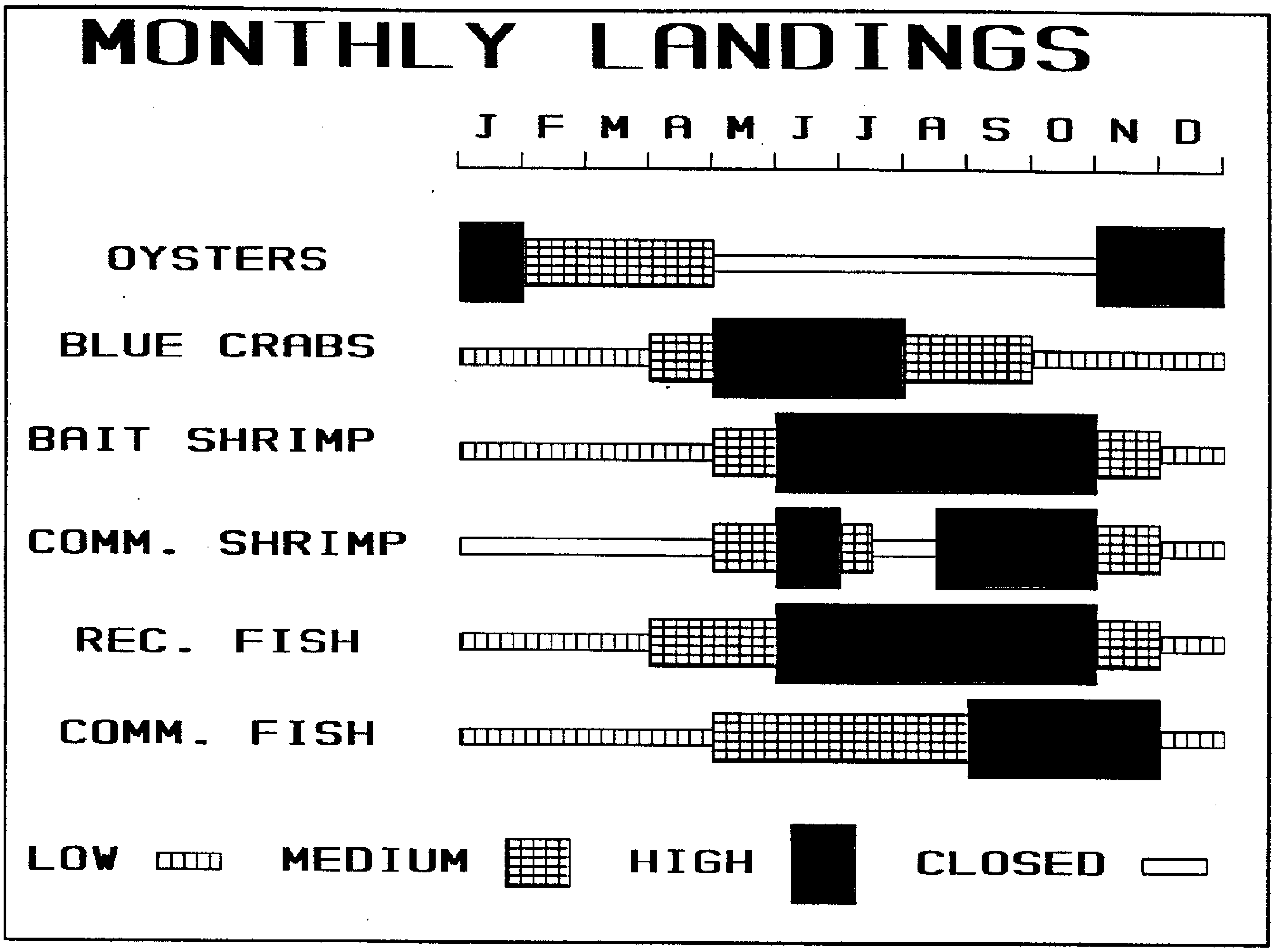

Figure 2.6. Seasonal landings by commercial (comm.) and recreational (rec.) fisheries in Galveston Bay (54, 56).

precisely where houses, industry, bulkheads and other of man's accomplishments are now located. Thus, the actual wetlands area will be much less than 360 square kilometers.

What does this signify for fisheries and for estuary-dependent species in general? As sea level rises and marsh retreat is impeded by civilization, the acreage of wetlands accessible to fishery organisms and contributing to their life cycles will decline, and shortly thereafter so will the fisheries that are currently harvested (58). In the meantime, marshes will be inundated for increasing amounts of time and thus will become "drowning" marshes on the way to extinction. This is a temporarily beneficial situation for the various fishes, invertebrates, birds, reptiles and mammals that utilize the marsh surface, since marsh utilization may be promoted by increases in (1) estuarine area, (2) duration of flooding and thus access, and (3) marsh-open water interface for materials exchanges. In other words, for an interim period greater marsh access could lead to greater system productivity (58).

Galveston Bay itself may be too small to detect the results of apparent sea level rise, although as mentioned previously shrimp catches are increasing and may be due in part to increased marsh access. However, on a Gulf of Mexico basis, the increased access to marshes due to drowning has led to detectable increases in recruitment of at least three commercial species for which a long-time series of data is available — gulf menhaden, brown shrimp and white shrimp (Figure 2.9) (58). From 1960 through 1985, catch statistics and population analyses have detected a 200 percent increase in the number of young gulf menhaden harvested and 50 percent increases in abundances of newly recruited shrimps. The effects of marsh disintegration are beginning to show up.

Freshwater Inflow and Saltwater Intrusion

Another problem facing the Galveston Bay biota is that of controlling fresh water and the associated change in salt water distribution. Two species of economic importance that are especially influenced by fresh water are oysters and white shrimp.

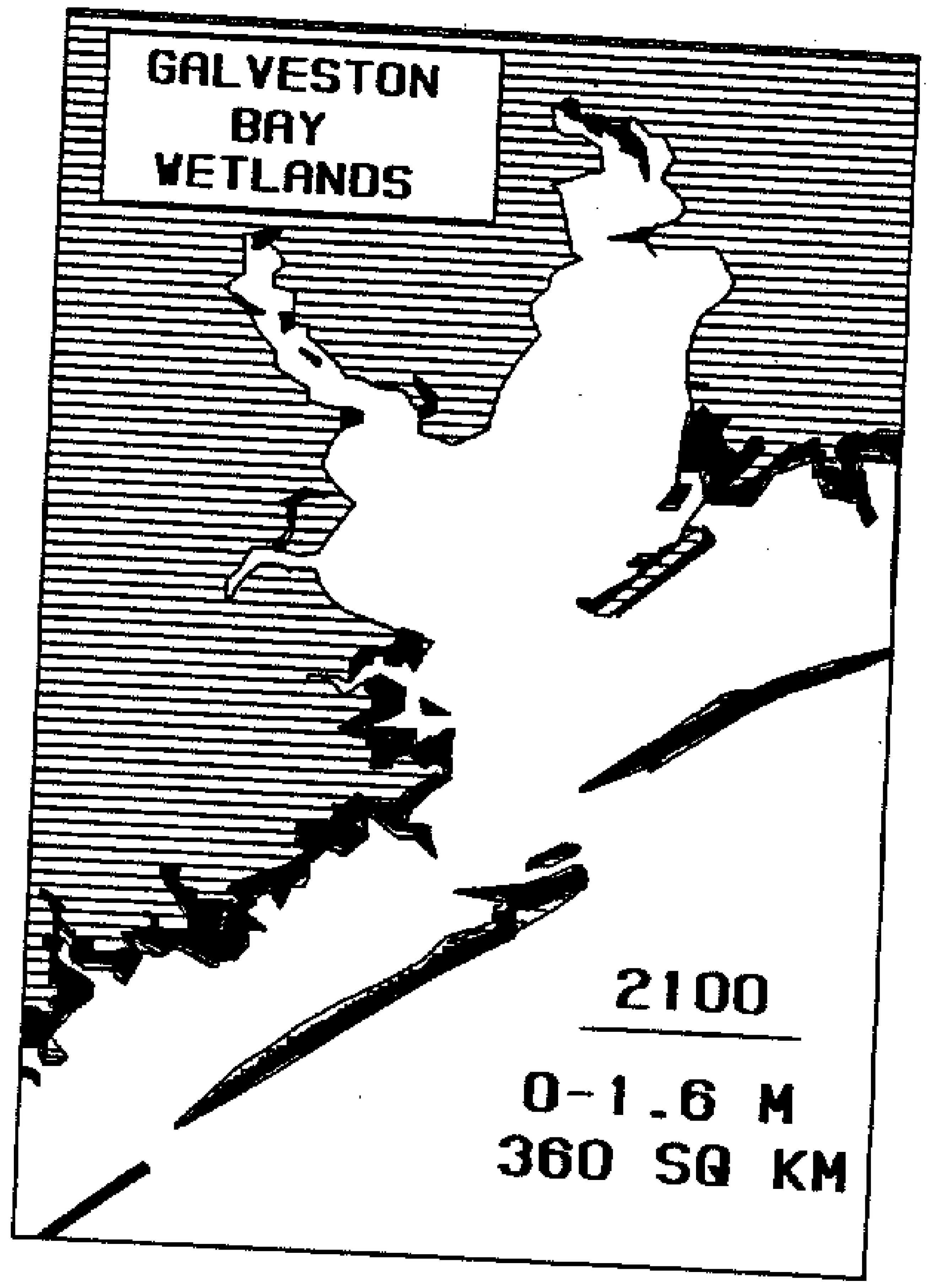

Figure 2.7. Low elevation areas (0-1.6 meters, shaded) where Galveston Bay wetlands were located in 1979, barring development (15).

Figure 2.8. Low elevation areas (0-1/6 meters, shaded) where future Galveston Bay wetlands could exist, barring development, after a 1.6-meter rise in sea level by the year 2100 (15).

Oyster survival and production are excellent indicators of the natural patterns of mixing of fresh and salt waters (19, 20). Under ideal situations oysters survive and grow well at salinities of 10 to 35 ppt. However, salinities of more than 20 ppt bring predators (such as oyster drills) and disease (such as "dermo") that decrease survival and production. Fresh water kills are also incurred if salinities drop below 10 ppt for extended periods or at the wrong time of year. The net result is the typical pattern of oyster reef formation primarily where waters are consistently 10 to 20 ppt. Major shifts in the seasonal timing or amounts of discharge from river systems could cause long-term changes in oyster reef distribution and production.

To a constricted arm of the Galveston Bay system, such as West Bay, a freshet of unrestricted flow can be quite beneficial for oysters. West Bay had been a high salinity-low production bay until a July 1979 tropical storm dropped 110 cm of rain in 24 hours (59). Salinities were dramatically lowered and, combined with subsequent high settlement of oyster spat, reported oyster harvest jumped from zero to1,225 metric tons in the November 1982 through April 1983 season and 907 metric tons the following season (Figure 2.10) (60). Since then, salinities have increased and reported oyster harvest has tapered off.

When fresh water inflow patterns are artificially altered, the results may not be so beneficial to white shrimp productivity. Sabine Lake is located between Galveston Bay and Lake Calcasieu, Louisiana. Dams were built on the Sabine and Neches Rivers in 1965-1966 that contained the natural peak river flows of January through May for later release in generating electricity in the normally low flow period of June through October (61). Portions of the surrounding marshes were also leveed off at the same time. These summer flood conditions negated recruitment of white shrimp to nursery areas by artificially lowering salinities to unacceptable levels. The Sabine Lake white shrimp fishery collapsed, while fisheries in Galveston Bay and Lake Calcasieu continue (Figure 2.11) (56).

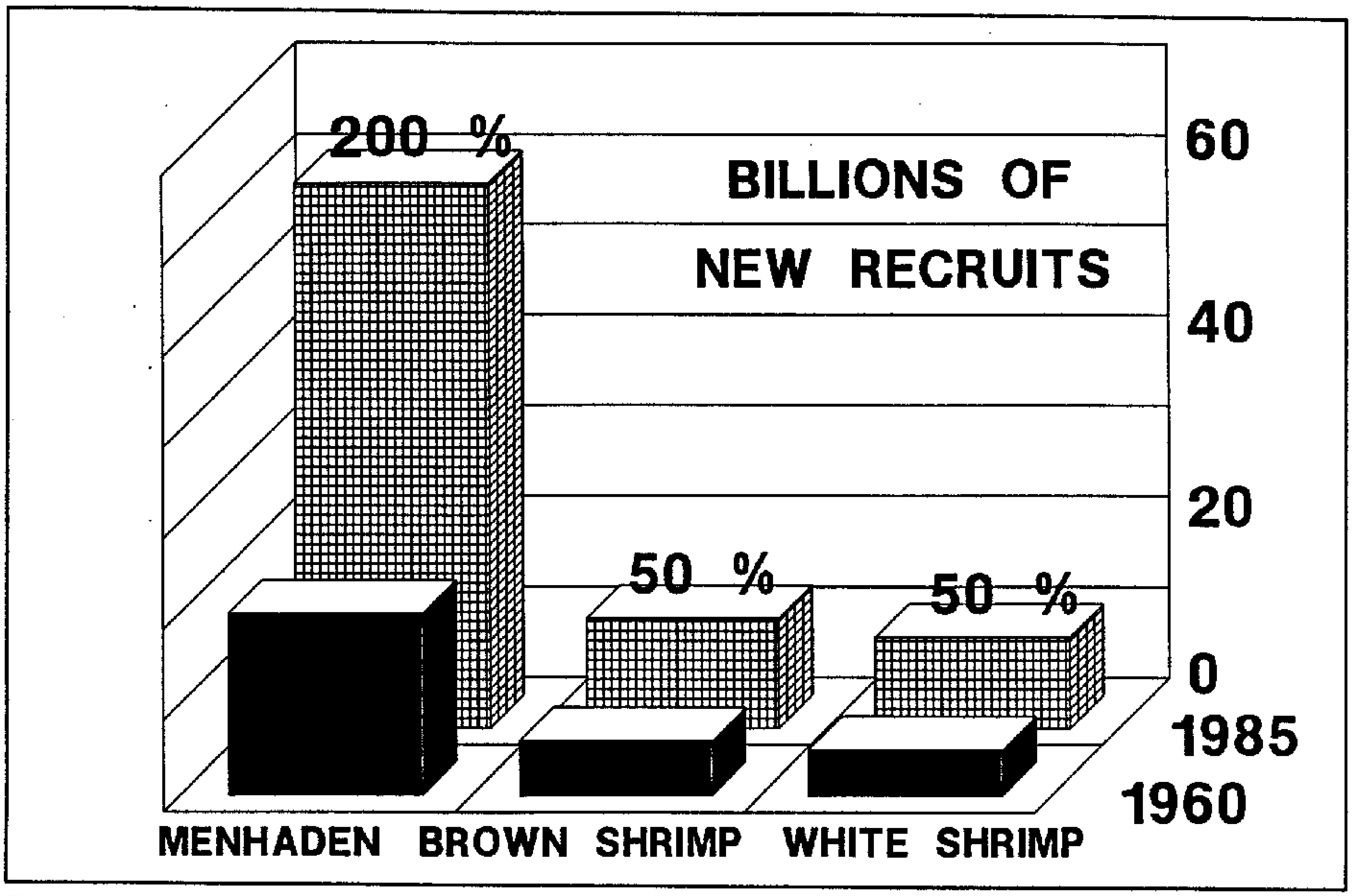

Figure 2.9. Increases in recruitment of menhaden, brown shrimp and white shrimp to U.S. Gulf of Mexico fisheries between 1960 and 1985 (58).

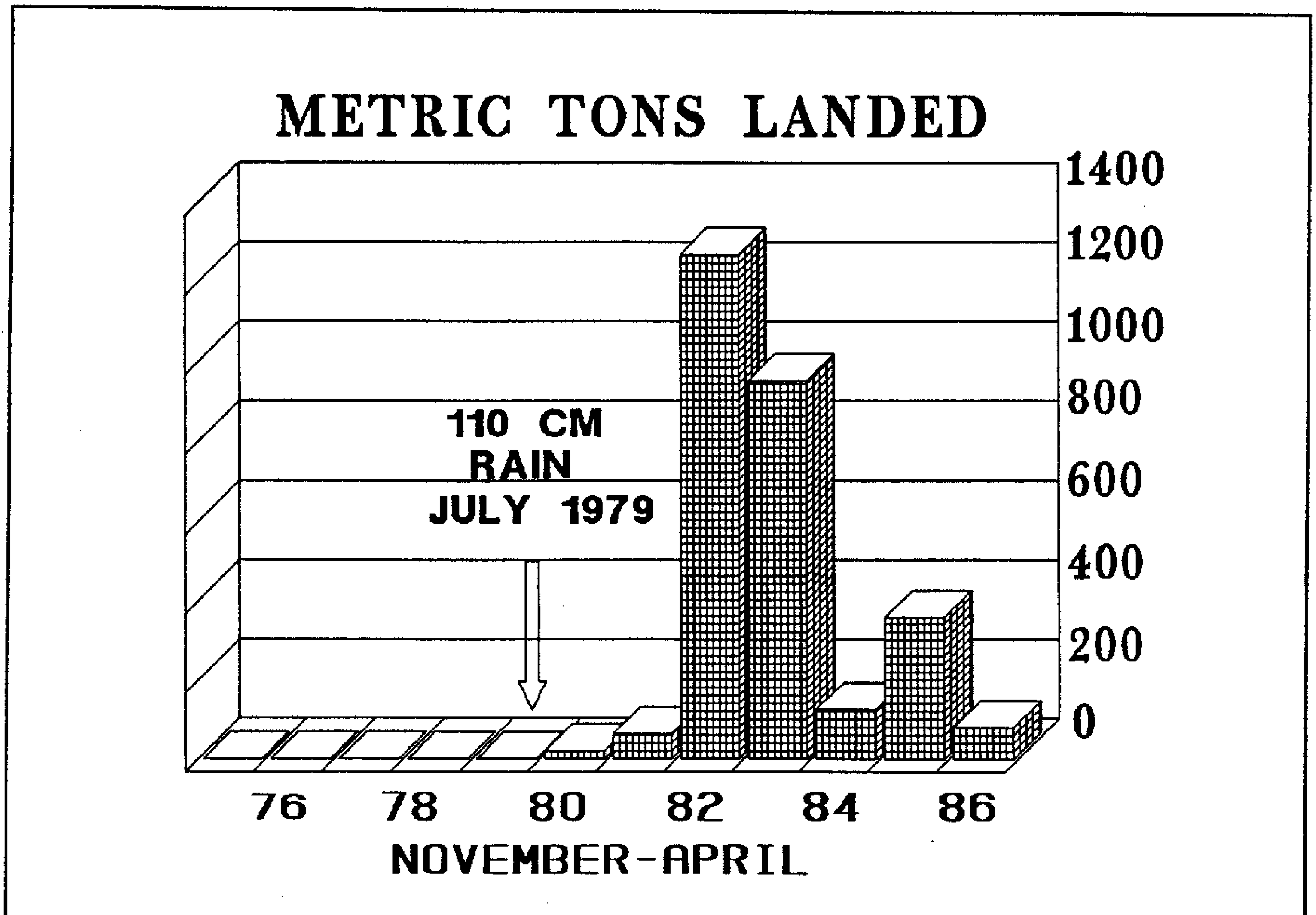

Figure 2.10. Oyster production from West Bay (1975-1986) following an unusual rainfall during a tropical storm that lowered bay salinities for an extended period (60).

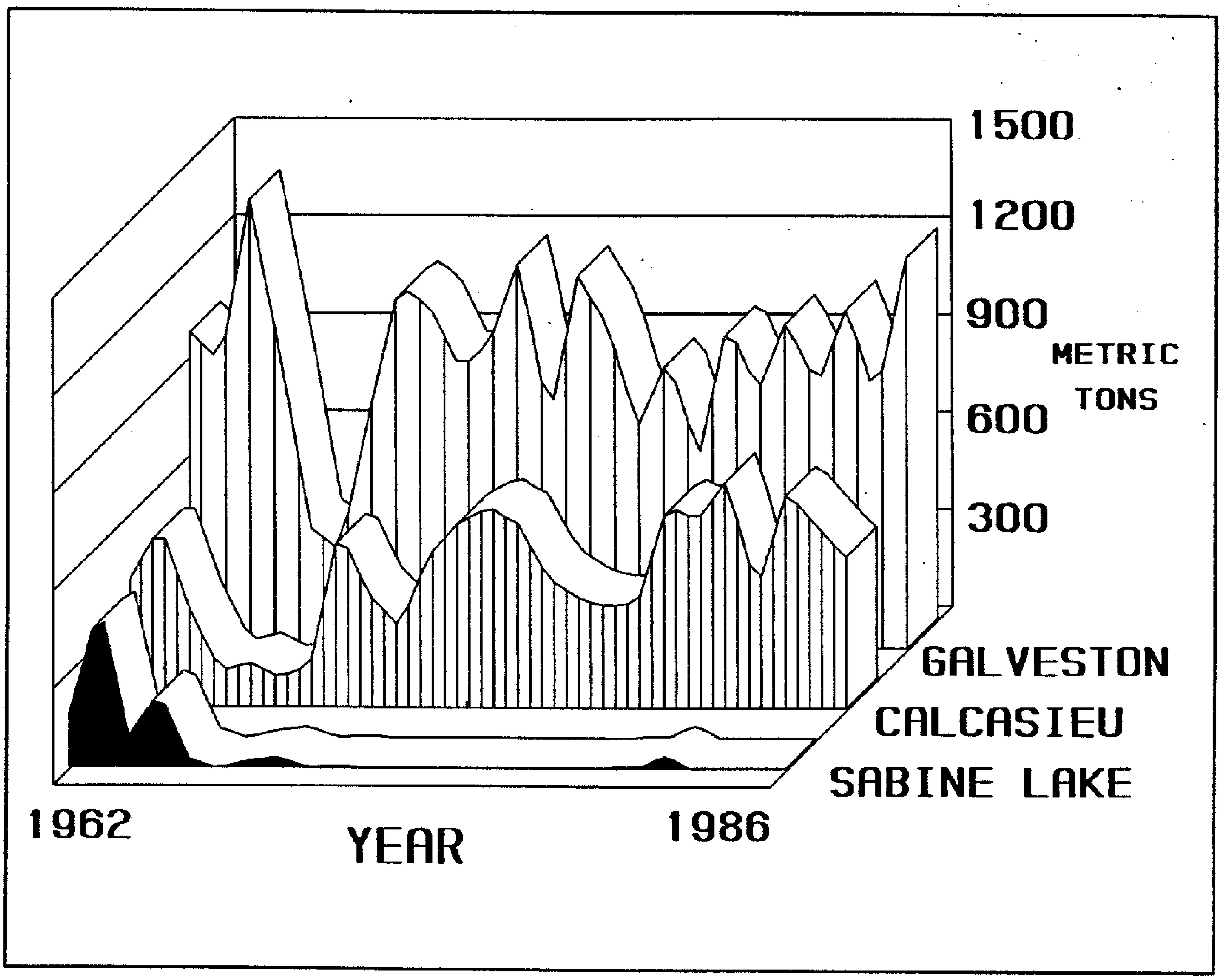

Figure 2.11. White shrimp production in Sabine Lake, Texas (1962-1986) before and after the Sabine and Neches Rivers were dammed in 1966 compared with landings in Galveston Bay and Lake Calcasieu, Louisiana (56).

Habitat Alteration

The linkage between abundance of (and access to) wetlands and system productivity has been discussed. Just where does Galveston Bay fall when habitat protection is mentioned? In 1979, the estuary was surrounded by approximately 715 square kilometers of wetlands (determined from maps in 15). Wetlands losses between surveys in 1956 and 1979, whether natural or due to human activities, have been severe (15). In the Marsh Point area of East Bay, subsidence and petroleum exploration canals led to a 26 percent loss of salt and brackish marsh to open water. Jones Bay, at the northeast end of West Bay, suffered a 37 percent loss of marsh area due to housing development and its location on the edge of one of the two major subsidence cones in the Houston area. At the mouth of the San Jacinto River, subsidence has caused a 42 percent reduction of fresh marshes and swamps. Seagrasses and other submerged vegetation, primarily found in West Bay but never very extensive, have declined precipitously by 95 percent on a baywide basis. Galveston Island itself has lost 37 percent of its wetlands due to housing projects and industrialization (62). For the entire estuary, a net loss of 16 percent of the vegetated wetlands occurred during the period 1956 through 1979. A complete system inventory is needed to determine what has transpired in the last eight years, a period during which Houston experienced a rapid population growth.

Conclusion

Given all the above information, a distillation of the material leads to three important facts to remember concerning the health of the Galveston Bay biota:

- There is a critical dependence of fish and wildlife on wetlands;
- A continued decline in wetlands acreage is foreseen; and
- The timing and amount of fresh water inflow are critical to the biota as we now know it.

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